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A. CONTRACT LINE ITEM NO. 0001AA

B. EXHIBIT A

C. CATEGORY: TDP ____ TM ____ OTHER TECHNICAL REPORTS

D. SYSTEM/ITEM Inexpensive Capillary Discharge XRay Laser

E. CONTRACT/PR NO. N00014-92-C-2218

F. CONTRACTOR MOXTEK

1. DATA ITEM NO. ~~A001~~ 0001AA

2. TITLE OF DATA ITEM Initial Technical Report

3. SUBTITLE

17. PRICE GROUP

18. ESTIMATED TOTAL PRICE

4. AUTHORITY (Data Acquisition Document No.) 47-2723-8-1794707 N0001492 WX20040/BASK

5. CONTRACT REFERENCE CLIN 0001AA

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16. REMARKS

THIS REPORT IS TO PROVIDE INFORMATION REGARDING PROGRESS UP TO DATE.

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INEXPENSIVE CAPILLARY DISCHARGE X-RAY LASER DRIVER.

INITIAL TECHNICAL REPORT FOR PHASE I

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A fully-implicit code to time-advance the 1-D MHD equations has been developed up to date specifically for modelling a capillary discharge (a radial dependence of parameters). Classical transport is assumed to have the correct dependence to within a multiplicative factor that can be specified at run-time. The atomic physics of the plasma is modelled using 0-D approximation where an "average" temperature and density are used to determine the ionization and recombination rates for the principal plasma species. These rates are then used to determine an "effective z" for the MHD model. It is assumed that the entire plasma is ionized to the same state. The model can currently treat elements up to z=18 (argon) due to limitations in the atomic physics portion of the code.

The code has been tested using some publeshed data from carbon capillaries [2,4] and the best fit corrections to classical transport have been determined for that type of discharge. Normalization of the code for an argon plasma has not been done due to a lack of published experimental capillary discharge data.

An extensive literature search for the previous capillary discharge experiments was performed and the result of this search is summarized in the Table 1. These experiments cover a plasma temperature range T_e =1-100 eV and a plasma electron density range $N_e=10^{17}-10^{20}cm^{-3}$.

From the point of view of plasma parameters a capillary discharge stays between z-pinch discharge (T_e > 100 eV, N_e> 10^{20} cm^{-3}) and high current ion laser discharges (T_e< 10 eV, N_e< 10^{15} cm^{-3})

In paper [4] the authors claimed they had registered the bursts of an amplified spontangeous emission (ASE) at 18.22 nm 3-2 transition in a H-like C. Authors estimated a gain $\alpha \cong 2\text{-}3\ cm^{-1}$. The bursts were very short (a few nsec), not reprodusible well, and they occured only in the middle of a second half-period of the discharge. According to [4], increasing or decreasing the capacitance of discharge capacitor or inductivity of a discharge circuit depressed the occurance of the bursts. No spectra of emitted lines were presented in the paper and no plasma diagnostics was performed.

In paper [9] a very high plasma temperature (100 eV) and density (10^{20} cm^{-3}) were reported for fluorine plasma, but it was not clear what was the feature size of such hot and dense plasma. These parameters are more likely connected with hot microscopic plasma volumes rater than with a bulk plasma. No spatially resolved diagnostics were reported here.

Table I. Summary of various capillary discharge experiments to date. Here: U_0, C_0, L_0, - discharge set parameters; I_0 - peak discharge current; j_0 - peak currend density, Z - discharge impedance, $Z=\sqrt{L_0/C_0}$; E_0 - stored energy; t/4 - discharge current rizing time; τ - discharge current exponential decay time; d x l - capillary geometry (diameter x length); W - energy contribution into plasma (J/cm^3), W = E/V; P- power contribution into plasma (W/cm^3) $P=W/\tau$; T_e- plasma electron temperature (eV) ; N_e- plasma electron density (cm^{-3}).

Ref #	U_0 (kV)	C_0 (uF)	I_{max} (kA)	j_{max} (MA/cm^2)	L_0 (nH)	Z (Ohm)	E_0 (J)	t/4 (ns)	d x l (mm x mm)
1	40	0.3	36	1	200	1.1	240	400	2x20
1	40	0.3	-		200	1.1	240	-	2x20
2	35	0.05	50	24	20	0.6	30	50	0.5x20
2	15	0.05	20	10	20	0.7	6	50	0.5x20
3	40	0.3	-	-	-	-	240	300	2x20
4	7	0.1	14*	2	15	0.5*	2.5	130	1x10
4	9	0.1	14*	8	15	1*	4.1	130	0.5x20,30
5	20	0.004	1.2	0.15	10	15*	0.8	50	1x300
6	10	0.12	5	0.01	600	2	6	400	7x1500
7	10	0.03	2	0.004	600		0.4		7x1500
8	25	0.12			80	2	38		0.4x13
9	250	-	100	10^4		3		10	1x10

*) calculated value

Table I. (cont.)

Ref #	τ (ns)	W (KJ/cm^3)	P (GW/cm^3)	T_e (eV)	N_e ($10^{19} cm^{-3}$)	$W \times N_e$ (KeV)	Element	Ion
1	1000	4	4	25	1	6	C	-
1	1000	4	4	12	0.7	9	Li	-
2	100	8	80	38	2.5	5	C	H, He
2	100	1.6	16	25	1.5	2	C	H, He
3	1000	4	4	20	0.6	11	Li	H,bare
4	250	0.3	1.2	-	-		C	H
4	250	1	4	-	-		C	H
5	90	3×10^{-3}	0.03	16	0.01	0.5	He	H-,
6	600	1×10^{-4}	1.6×10^{-4}	3*			Kr	3+,4+
7	-	5×10^{-6}	-	5*	-		Ne	3+
8	200	23	110	20	5	7	O	4+
9				150ˣ	10ˣ		Fˣ	H,ˣ Heˣ

ˣ) At a current exceeding 10^2 KA a plasma in a capillary discharge collapses and noted parameters (as well as the ionization power) do not reflect parameters of a bulky plasma.

*) calculated values

References for Table 1.

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